which we were enabled to keep the secretions from accumulating in the chest, and thus allowing the walls of the immense abscess to approach each other, and finally to obliterate the cavity. In the numberless introductions of the catheter, a single bubble or two of air was the most ever allowed to enter, and then at the moment of its withdrawal. I note this case in hopes that this process may be thought worthy of a trial, by some more experienced hand.

A case of abscess of the chest, of some interest, occurred a few years ago in the upper part of this state, in the practice of a medical friend, and was cured in a way somewhat *unique*, which would seem to make it worthy of recital.

A man was seized with some affection within the thoracic cavity, which resisted the prescriptive treatment of his physician. The stethoscope at that period had not come into general use, and the case was so ambiguous, that its character was not revealed by its symptoms. The patient and his friends entertained the opinion, that he was labouring under pulmonary consumption. No swelling, no discoloration, existed externally upon the thorax; but the patient, from the internal sensation produced by the disease, had a settled conviction that there was a *gathering* within. Taking a seat by an unfrequented side of the house, he plunged the blade of his penknife opposite the seat of pain between the ribs. He was found with pus flowing from the wound; a large quantity was discharged from the narrow wound. From that time his symptoms were relieved, and the patient finally recovered.

Art. IX. *On the Penetration of Gases.* By J. K. Mitchell, M. D. Professor of Chemistry, &c. in the Franklin Institute, and Lecturer in the Medical Institute.

In the November No. of this Journal for 1830, I published a paper, on the force and ratio of transmission of gases through membranes. The subject has since that period attracted much attention, both here and in Europe, and the experiments then made, have become the basis of reasoning on many morbid phenomena, and some physiological functions, particularly that of respiration. These considerations have led me again to review the experiments made at that time, and to make others, which seemed necessary to the full elucidation of the subject. This labour became the more necessary, since Mr. Graham, of Glasgow, a chemist of growing reputation, has, in the course of an experimental investigation of the transmission of gases through stucco

plugs and other inorganic substances, confounded together two very different actions, and thus thrown some obscurity over the whole subject.

In 1829 I believe, Mr. Graham attempted to ascertain with accuracy the law by which the gases intermingle, or are diffused through one another. Mr. Dalton had previously shown, that when two gases of different specific gravities are placed in contact, so that the heavier gas shall be beneath the other, they notwithstanding, gradually commingle, even if a *long narrow tube* be the only connecting medium between their respective reservoirs. These and other facts led Mr. Dalton to conclude that each gas is repulsive only of itself, and that its interstices are a *vacuum* for the reception of any other gas whatever. The fallacy of that view of the subject might have been made out by the fact, that the commingled gases occupy as much space as when existing separately, and therefore cannot be supposed to enter the interspaces of each other as into a *vacuum*. The first *experiment* however, which demonstrated the error, was that recited in my first paper, showing that the force of 'diffusion,' as well as of 'penetration,' exceeded by an unknown quantity, the pressure of two atmospheres. Mr. Graham, by confining gases in vessels communicating with the air by narrow apertures, found that the ratio of diffusion varied inversely as the square root of the density. In a paper read before the Royal Society of Edinburgh on 19th of December, 1831, more than a year after the publication of my paper, Mr. Graham describes a series of experiments on 'diffusion,' made by the intervention not of artificial apertures, but of plugs of stucco in which the pores are minute enough to oppose a *slight* resistance to the mechanical escape of aerial fluids. By placing various gases in a glass vessel closed at one end by a stucco plug, and resting on mercury or water, and observing the time taken to escape, and the volume of reëntered atmospheric air, he formed the following table.

Table of Equivalent Diffusion Volumes of Gases, air being 1 *or Unity.*

		Specific Gravity.
Hydrogen	3.83	0.694
Carbureted hydrogen	1.344	0.555
Olefiant gas	1.0191	0.972
Carbonic oxide	1.0149	0.972
Nitrogen	1.0143	0.972
Oxygen	0.9487	0.111
Sulphureted hydrogen	0.95	1.1805
Protoxide of nitrogen	0.82	1.527
Carbonic acid	0.812	1.527
Sulphurous acid	0.68	2.222

Thus his former conjecture was confirmed, and he appears to have

proved that 'diffusion' is inversely as the square root of density. As the pores of stucco, charcoal, paper, &c. are penetrated with great ease by the gases, the quantity constantly presented at the surfaces of the stucco is greater than the diffusive power is capable of conveying away, hence only the 'diffusion' can be thus exhibited, since the amount of 'penetration' is limited to the quantity removed by the air. The removal more rapidly by a current or a *vacuum*, greatly increases the amount effused, showing the much greater 'penetration.' Substantially in the former paper, I stated that when the 'penetration' exceeded the 'diffusibility,' only the latter could be measured, whereas, when the diffusion is greater than the penetration, it is the action of the barrier which is estimated. Overlooking this distinction, Mr. Graham has confounded together all kinds of penetrable barriers, and asserts that "dried bladder answers for showing the *diffusion* of hydrogen when stretched over the open end of the tube receiver; the diffusion however, through a single thickness of bladder is effected at least twenty times more slowly than through a thickness of one inch of stucco; while on the other hand, either air or hydrogen, under mechanical pressure passes more rapidly through bladder than through a great thickness of stucco. Goldbeaters' skin is even more permeable by gases under slight pressure than bladder, and less suitable for diffusion." pp. 240, 241. That Mr. Graham has fallen into unaccountable error in this particular, is demonstrable by the following simple experiment.

Over the end of a tube eight inches long was tied a piece of moistened bladder, which was subsequently dried. The tube was then filled with mercury, and placed erect on the mercurial pneumatic shelf, by the side of a similar and similarly treated tube closed with stucco. In less than three minutes the air had passed through the stucco, and followed the mercurial column down to the level of that in the trough. In the other, in *twelve hours*, enough of air had not entered through the bladder to disengage the mercury from its contact with it. It amounted to a small bubble floating about against the under surface of the bladder. To secure to the bladder complete contact with the glass, it must be tied on when wet, with a dry *waxed* string, and then left some hours to dry. Any tube thus treated will admit air by *mechanical* impulsion *many thousand* times more slowly than stucco of an inch in thickness. When it does otherwise it is unsound or imperfectly tied on. Whenever the hydrogen finds its way out by a passage between the glass and bladder, it diffuses more rapidly than carbonic acid, and only then.

Another experiment made with a different object demonstrates the same fact. Three tubes each six inches in height and capable of

holding two cubic inches of air were closed with bladder at one end, and filled half-full of nitrogen, hydrogen and oxygen respectively, so that each tube being placed over water, held a column of that liquid nearly three inches high. Notwithstanding the pressure inwards, the tubes all of them fully supported the columns, and at the end of five days they all contained less air and more water than at the beginning. No stucco plug would support a three inch column of water for five minutes.

Notwithstanding these discrepancies, I thought it important to go again into an examination of the 'penetration' of gases, and to write on the subject a series of papers, of which this, the first, will contain little more than an experimental review of ground formerly, but hastily traversed. The great importance of the subject, seem to me to justify the repetition of the experiments which will be reported more in detail than the former ones.

The annexed wood cut represents the inverted syphon with which a great many of the following experiments were made. Enlarged at one end into a kind of funnel or inverted cone, $\frac{7}{10}$ths of an inch in diameter, over which the membrane is tied, its other limb $\frac{2}{10}$ths wide, is graduated into divisions of equal lengths, of the capacity of 0.003 of a cubic inch. Under the membrane were placed 0.075 of a cubic inch of atmospheric air, which was confined there by mercury having the same level in both limbs of the syphon. Thus prepared, the funnel of the syphon was pressed under mercury and brought up into a bell-glass, holding two and a half cubic inches of the gas to be tested. The rise of the column of mercury in the outer limb indicated the velocity of influx, and the quantity. In the first series of experiments exhibited in the following table, gum-elastic was used as the barrier. Its flexibility when dry, its refractory character, its feeble hygrometric power, well fit it for a standard of comparison.* The whole of the experiments arranged in the first table, were made with the same membrane, so that, making allowance for the effect of dust, mercury, and the irregular manner in which quicksilver moves in a narrow glass tube, the various results by the same gas are very uniform.

Fig. 1.

* In a very thin, transparent bag of gum-elastic were placed ℥4. ʒij. 57 grs. of water, which lost in weight per day as follows:—8 grs., 4 2-3, 6, 3 3-5, $4\frac{1}{4}$, $3\frac{1}{8}$, $3\frac{1}{2}$, $3\frac{1}{2}$, 2, 0, $2\frac{1}{3}$, 2, 2, $1\frac{3}{4}$, &c. The average loss for one hundred and twenty-nine days was 2.367 grains per day.

A section of bladder tied up in the form of a bag, and holding 4oz. 6ʒ. 2 grs. of water lost per day 259 grains, 117, 303, 621, when it became offensive.

TABLE I.

Of the Rate of Entrance of Various Gases through Gum-elastic into Atmospheric Air confined in the Inverted Syphon, Fig. 1.

No. of spaces.	Sulphureted Hydrogen.			Cyanogen.			Cyanogen.			Cyanogen.		
	Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.	
	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.
1	80 F.	1	47	70	1	45	71	2	45	73	1	
2		1	14		1			1	3		1	35
3		1	8		1			1	12		1	15
4		0	51		1	10		1	4		1	3
5		1	7					1	23		1	13
6		1	5					1	17		1	16
7		1	26					1	28		1	22
8		1	24					1	48		1	30
9		1	41					1	42		1	47
10		1	20					1	20		1	40
11		1	44					1	31		1	35
12		1	51					1	53		1	29
13		1	55					1	36		1	56
14		1	50					2	13		1	42
15		1	33					1	49		1	50
16		2	24					2	25			
17		2	16									
18		2	6									
19		2										

No. of spaces.	Ammonia.			Ammonia.			Ammonia.			Carbonic acid.			Carbonic acid.		
	Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.	
	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.
1	68	2	15	68	2		68	1	60	68	6	15	68	5	45
2		1	15		1	45		1	35		5			4	30
3		1	30		1	·45		1	50		4	23		4	45
4		1	30		1	45		1	45		4	14		5	45
5		1	45		2			1	45		5	15		5	45
6		2	30		2	15		1	30		5	30		6	
7		1	45		2	30		1	45		6	14		5	45
8		2			3	15		1	30		7	15		8	10
9		2			3			2	15		7	38			
10		2	30		3	15		1	50		6	45			
11		1	46					2	5		7				
12		2	45					2	30						
13		2	15												
14		3													
15		2	30												
16		2	45												
17															
18															
19															

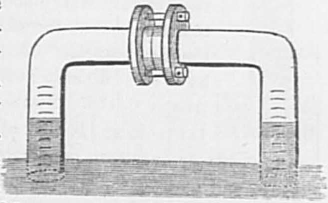
No. of spaces.	Hydrogen.			Hydrogen.			Oxygen of nitre.			Oxygen of Chl. of pot.			Oxygen to nitrogen.		
	Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.		Temperature.	Time required.	
	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	Deg.	Min.	Sec.
1	70	25	15	70	25		74	32	45	75	42		79	40	
2		15			19			32			42			40	
3		16			17	30		45			44	30		45	
4		14	45		15	30	76	45						50	
5		16	45		19			57	30					70	
6		20			22			56							
7		22	45		22	15		76	30						
8		24	30		25	15		93	30						
9		25						96	30						
10		25	40					107							
11		28	50					155							
12		36	30												
13		41													
14															
15															
16															
17															
18															
19															

The average rate of penetration is *inversely* as the following numbers.

Sulphureted hydrogen, 1; cyanogen, 1.166; ammonia, 1.75; carbonic acid, 4.50; hydrogen, 15; oxygen, 35; or taking the least number of each column, we have—sulphureted hydrogen, 0.85; cyanogen, 1; ammonia, 1.25; carbonic acid, 4.233; hydrogen, 14.75; oxygen, 32. As these numbers are also inversely representatives of the quantities of the gases admitted in equal times, it follows that nearly fifteen times as much cyanogen enters in a given time as of hydrogen, whereas according to Graham, hydrogen should enter in about four times the measure of cyanogen.

In the instrument, Fig. 2, some of the gases were compared, so as to verify the results of the first table, the intervening membrane being also gum-elastic. The instrument consisted of two hollow cylinders of iron or brass with flanges and screws so that they might be forced into powerful contact. To accomplish this the better, the screws had perforated heads through which a lever could be passed. Between the shoulders of the cylinders, was placed the membrane, and by means of the screws and levers, the shoulders of the cylinders tightly compressed the membrane, so as to entirely cut off communication with the air at the point of contact. Into the cylinders were fixed by sealing wax curved glass limbs, of equal length and diameter, so that when put together the whole represented an inverted syphon open at each end, but separated into two compartments by the membrane at its middle point. By placing measured quantities of the gases to be compared, on opposite sides of the membrane, the experiment commenced under perfectly equal circumstances. The quantities were alike, they were on the same level at the membrane, and were subject to equal causes of tension. But few observations were thus made on gum-elastic, and these merely to verify the results presented by the funnel-syphon. Carbonic acid was found to be more penetrant than hydrogen, hydrogen than oxygen, and oxygen than nitrogen, made both by phosphorus and hydrogen. The exact degree was, for want of time, overlooked.

Fig. 2.

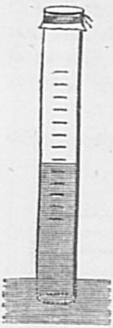


Another general verification was made in simple tubes standing erect over mercury or water, and covered with the same kind of membrane. In these cyanogen was more penetrant than carbonic acid, that than hydrogen, that than oxygen, and nitrogen scarcely ever

suffered any other change than that produced by alteration of temperature. In the next paper more exact results will be given.

Before proceeding to the action of gases on wet animal membranes and recent animal tissues, some observations were made on dry bladder. A tube Fig. 3 was filled to the top with mercury—after standing over the mercurial trough all night, a very small bubble of air was observed among the mercury yet in contact with the membrane. A similar tube closed with a plug of stucco an inch in depth suffered the air to enter so rapidly as to let the mercury fall to the level of that in the trough in a few minutes. Having ascertained in this manner the tightness of the membranous cover of three equal tubes, a cubic inch of hydrogen, oxygen and nitrogen respectively was placed in them. By transfer to water that liquid took the place of the mercury without wetting the membranes. After five days the hydrogen was less by 0.38 of a cubic inch, the oxygen by 0.08, and the nitrogen 0.015. Stating the rate of hydrogen as in the 1st table at 15. that of oxygen will be 3.158, and of nitrogen 0.58: or hydrogen penetrates nearly five times as rapidly as oxygen, and that nearly six times as rapidly as nitrogen, when dry bladder is used for the cover, and the gases stand over water.

Fig. 3.



A syphon, Fig. 2, contained in its limbs 125 parts of hydrogen and carbonic acid respectively. A perfectly dry bladder intervened, and was compressed by the shoulders of the iron as forcibly as possible. At the end of twenty-four hours, of the 125 parts of hydrogen 2 passed to the carbonic acid *through* the membrane, 51½ by the space between the iron shoulder and bladder to the air, and by the same way there reëntered 30⅔ds of common air.

Of the 125 parts of carbonic acid 5 passed through to the hydrogen, 30½ passed by the side of it to the air, and the reëntered air measured 25½.

Penetration through dry bladder—hydrogen 2, carbonic acid 5, or 1 to 2.5.

Diffusion by the side of the membrane—hydrogen 51.5, air 30.666, or 1.68 to 1; carbonic acid 30.5, air 25.5, or 1.196 to 1.

Experiments on the penetration of gases through wet and recent animal tissues.

The syphon, Fig. 1, used for the experiments arranged in Table I. containing the same quantity of atmospheric air, was covered with bladder soaked in water until perfectly infiltrated, and then wiped dry on the surface. It then, by immersion in the following gases, gave the results stated in Table II.

TABLE II.

Rates of Penetration through wet Bladder in Syphon, Fig. 1.

Nos.	Ammonia.		Ammonia.		Cyanogen.		Cyanogen.		Carbonic acid.		Carbonic acid.		Hydrogen.		Hydrogen.	
	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Min.	Temp.	Min.
1	72°	8	72°	11	71°	49	69°	50	69°	224	71°	228	72°	38	70	37
2		12		10		66		62		214		194		30		34
3		11		9		55		48		193		192		31		31
4		8		8		46		44		158		193		37		
5		10		10		54		51		228		225				

Ratio—1 to 5.5—20.7—600.

TABLE III.

Rate of Penetration through the Crop just taken from a Chicken, and tied over the end of the Syphon, Fig. 1.

Nos.	Ammonia.		Ammonia.		Ammonia.		Cyanogen.		Cyanogen.		Carbonic acid.	
	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.	Temp.	Sec.
1	72°	8	71°	8	73°	8	71°	45	69°	55		156
2		10		10		6		43		46		139
3		14		14		5		41		36		95
4		18		18		5		27		28		115
5						8*		47		42		137

Ratio—1 to 4—12.3.

The piece of paper containing the account of the experiments on oxygen for Table II. and of oxygen and hydrogen for Table III. having been mislaid, I am able to recollect merely the general agreement exhibited by the other gases. Oxygen penetrated somewhat more slowly than hydrogen.

Experiments on the penetration of gases through wet and fresh animal tissues in the inverted syphon, Fig. 2.

1st. Over mercury 0.85 of a cubic inch of carbonic acid and oxygen from nitre were placed in the opposite limbs of syphon, Fig. 2, separated from each other by wet bladder. In twenty-five hours the carbonic acid was lessened to 0.355, which lost by washing 0.330, leaving behind 0.025 of oxygen. The contents of the other limb were

* Immediately after an experiment with any gas, a repetition with the same membrane and gas usually showed acceleration.

lost without admeasurement, but were greater than at the beginning of the experiment.

2d. Repeated. 1.10 parts of carbonic acid, 0.85 parts of oxygen, after twenty-one hours found the carbonic acid reduced to 0.63, which lost by washing 0.605, leaving 0.025 for the oxygen sent through.

The other limb contained 0.965, lost by washing 0.30; 0.30 of carbonic acid and .025 of oxygen went through the membrane, which held in its pores 0.195 carbonic acid and 0.155 oxygen. Or carbonic acid is ten times as penetrant as oxygen.

3d. Repeated. Carbonic acid 1.35, oxygen 0.85, after a lapse of nineteen hours and fifteen minutes the gas in the carbonic limb was 0.88, lessened by washing to 0.05; while the other limb contained 1.125, reduced by washing to 0.785—so that 0.34 of carbonic acid penetrated, and 0.18 were absorbed; while 0.05 oxygen penetrated, and 0.015 was absorbed; or carbonic acid is more than six times as penetrant as oxygen.*

4th. Repetition. Substituting *fresh* chicken *crop* for the wet bladder—1.35 of carbonic acid, and 0.85 of oxygen—time, twenty-seven hours and thirty minutes. The carbonic acid limb contained 0.35, which by washing was reduced to 0.05; the other limb held 1.55, reduced by washing to 0.80—so that 0.75 of carbonic acid and 0.05 of oxygen penetrated, while the membrane held 0.50 of acid, and none of the oxygen. According to this experiment, carbonic acid penetrates fifteen times as rapidly as oxygen.

In the same syphon, Fig. 2, by the intervention of wet bladder, hydrogen and cyanogen were compared. In these experiments equal quantities were used. The column of mercury rose in the limb containing cyanogen, and fell in that holding hydrogen, thus indicating the superior penetrancy of the heavier gas.

2d. Repeated. The hydrogen received twenty parts of cyanogen, and transmitted only one part.

3d. Repeated. Twenty-eight parts of cyanogen, and nearly one and a half of hydrogen permeated the wet bladder.

1st. Hydrogen and nitrogen compared over water by wet bladder. Time nine or ten days; instrument, Fig. 2; quantity 2.55 of each; temperature ranged between 69° and 78° Fahr. By Hare's eudiometer the hydrogen was shown to hold 0.289 of nitrogen, the nitrogen 0.50 hydrogen, hydrogen therefore penetrated 1.724, nitrogen 1.0.

* After observing the great amount of absorption by the wet membrane, I increased the proportional quantity of the more absorbable gas.

1st. Comparing oxygen and hydrogen in the same manner with intervention of fresh crop—after two days the greater penetrancy of hydrogen could be seen by the change of volume, which was not however very considerable.*

Experiments to ascertain the full result of penetrant action through wet bladder.

To effect this object, a syphon similar to that represented in Fig. 1, was so adjusted, that its outer limb at A being made short, it could *discharge* the mercury in proportion to the influx of gas at the other end, without *very materially* altering the pressure. The mercury discharged represented the quantity of aerial influx through the membrane, or rather the difference between the penetrant action of air and the gas. The wide end of the syphon contained 0.25 parts of a cubic inch of air, the bell-glass nearly a pint of gas. The first experiment was made with ammonia at the temperature of 69° Fah. After a lapse of between thirty minutes and an hour in all cases, the ammonia seemed to cease action, and the quantity of mercury thrown out, was in three different cases 1.025, 0.90, and 0.975 respectively.

Cyanogen. Under the same circumstances took at least eight hours to complete its action, and the quantity of mercury thrown out varied from 0.90 to 1.00.

Carbonic acid did not cease action for nearly three days, when it was found that 1.125 parts of mercury were discharged.

In a second experiment .555 parts were discharged in twenty-five hours; in the next twenty hours and fifteen minutes, 0.15; in the next twenty-four hours and ten minutes, 0.075; and in the nineteen hours and thirty minutes immediately preceding the cessation of action, 0.02. Total, with correction for temperature and pressure, 0.98, in about three and a half days.

Hydrogen under a similar arrangement discharged 0.045 in eleven hours and fifteen minutes; 0.025 in seven hours and fifteen minutes; 0.045 in sixteen hours; 0.07 in twenty-five hours and fifteen minutes. Total after correction, 0.205, in fifty-nine hours and forty-five minutes, at which time an accident put an end to the experiment, while it was yet in action. From the experiments immediately antecedent, it is probable that the amount would finally have reached about 0.95 to 1.00, or a cubic inch; or, as in the other cases, 0.25 of air would

* In the last two experiments nothing is certain but the greater penetrancy of hydrogen over either oxygen or nitrogen, for the motion in the limbs of the syphon showed that. In both, the bladder began to spoil at the end of the experiment.

mingle with 1.00 of gas, the proportion being about 4 to 1, as in the mixture of nitrogen and oxygen in the atmosphere. The penetration of *air* through wet membranes is so slow, as to leave scarcely a trace of such action by analysis, even in the most protracted experiments. I have therefore made my calculations without introducing it.

From these experiments it appears that the rate of influx was very great or rapid for ammonia, much slower for cyanogen, still slower for carbonic acid, and very slow indeed for hydrogen. Ammonia completed in half an hour the penetration which required eight hours for cyanogen, three days for carbonic acid, and an unknown, but much longer time for hydrogen. The latter in two days and a half had done about one-fiftieth of the work executed by ammonia in half an hour. It is, however, to be observed, that the exact time for ammonia was not well observed, and it may have been misstated, but not to an extent exceeeding half an hour.

In the attempt to discover the cause of the difference of velocity of the transmission of gases through porous bodies, I examined experimentally the passage of compressed aeriform fluids through visible apertures. Condensed to an equal degree in the same reservoir, air, hydrogen, and carbonic acid were successively allowed to escape through an aperture distinctly visible, and the times of the descent of the mercury of an air-guage noted in *seconds* as it passed over equal spaces, falling from nearly four atmospheres to the usual barometric level.

Hydrogen—11, 10, 7, 6, 7, 5, 5, 5, 5, 4, 5, 3½, 4, 5, 6, 8, 22.

Carbonic acid—36, 33, 25, 24, 21, 17, 18, 16, 13, 14, 14, 12, 14, 14, 16, 22, 29.

Ratio on the whole, 1 to 3.163.

Through a smaller aperture just visible the times of escape were in seconds.

Hydrogen—19, 16, 15½, 14, 14½, 12, 12½, 10½, 14½, 14, 17, 27.

Carbonic acid—51, 45, 47, 41, 36, 34, 35½, 31½, 38, 37, 42½, 61½.

Common air—43, 40, 40, 35, 32, 31, 31, 26, 33, 32, 38, 55.

Ratio—1 to 2.688—2.344.

A repetition gave very similar results. The air escaped more rapidly than carbonic acid.

A stucco plug a quarter of an inch in length was next used under like circumstances, care being taken not to compress it. The results were in seconds.

Hydrogen—74, 76, 78, 79, 80, 85, 90, 93, 98.

Carbonic acid—158, 155, 151, 159, 149, 174, 181, 180, 203.

Common air—173, 163, 169, 172, 167, 188, 200, 198, 215.

Ratio—1 to 2.005—2.18. The air penetrates with less facility than carbonic acid.

Through a *compressed* stucco plug rather more than an inch in length the times of escape were in minutes, as follows:—

1st. Hydrogen—$12\frac{1}{3}$, 11, $13\frac{1}{3}$, $14\frac{1}{2}$, $13\frac{1}{2}$, $15\frac{1}{4}$, 18, $18\frac{1}{4}$.
2d. do. $10\frac{1}{2}$, 11, $12\frac{1}{2}$ $13\frac{2}{3}$, $12\frac{2}{3}$, $13\frac{1}{3}$.
1st. Carbonic acid—17, $18\frac{1}{3}$, $21\frac{1}{3}$, $22\frac{1}{2}$, 22, $25\frac{1}{2}$, 29, $29\frac{2}{3}$.
2d. do. 17, $18\frac{1}{3}$, $20\frac{1}{4}$, $20\frac{3}{4}$.
1st. Common air—$20\frac{3}{8}$, 21, $23\frac{1}{2}$, 25, $24\frac{1}{4}$, $27\frac{1}{4}$.
2d. do. $19\frac{1}{4}$, 20.

Ratio—1 to 1.626—1.727. The air penetrates with less facility than carbonic acid.

Recapitulation.

	Hydrogen.	Carbonic acid.	Air.
Ratio of times—visible hole	1 - -	3.163 - -	
Lesser aperture - -	1 - -	2.688 - -	2.344
Thin plug of stucco - -	1 - -	2.005 - -	2.18
Thick dense plug - -	1 - -	1.626 - -	1.727

It seems, if these experiments can be trusted without frequent repetition, that the larger the orifice the more nearly the proportional quantities of gases given out in a certain time approach to Graham's law of diffusion; and that the more minute the apertures the less the porportional facility of the escape of the lighter gas. Thus, air passes through a visible aperture faster than carbonic acid, but not so fast through the pores of stucco—while the proportional rapidity of the escape of hydrogen is greatest through the widest aperture, and though greater in the smallest, yet progressively lessened. It passes through a large opening 3.163 times as fast as carbonic acid—through a smaller one 2.688 times as fast—through a thin plug 2.005 times as fast, and through a thick one only 1.626 times as fast. By still more minute channels it is possible that these two gases may pass with about equal facility, and pores may exist so minute as to reverse the order of penetration, as is demonstrated with respect to carbonic acid and common air in these very experiments.* The experiments to bear on this question are yet in progress, but those which exhibit the transmission through gum-elastic, wet bladder, and recent animal membrane, demonstrate, if not the cause, at least the fact of a reversal of the order of penetration; for through such in all instances the heavier gas penetrates much the more rapidly. If the size of orifice determine the penetration, philosophy may yet, by experimental investigation of

* See page 106, where carbonic acid diffused to hydrogen by the side of a membrane, as 1 to 1.404.

the effects of apertures of visible but varied size, learn the law of alteration, and thus finally, by observing the penetration through invisible pores, calculate their size, even determine the volume of the penetrant atoms, and detect many mysteries of physiology and pathology, by a process which at first seemed to promise no contribution to the stores of useful science.

Other and indispensable engagements forbid my entering at present on a record of the many very interesting suggestions forced on us by the facts which have been here recorded. But they will have more weight when they follow the whole series, which I hope to lay soon before the readers of this Journal. For the imperfection of very many of my experiments I must be indulged, since the calls of an arduous and imperative profession often interrupted, and sometimes destroyed the most promising phenomena. To present them as they are, it was necessary to work during the night, and sometimes all night, a period not very favourable to nice observation and delicate manipulation. But though imperfectly, they are honestly made, and to avoid obscurity the prolix details have been stated at length, and the reader has thus the opportunity of judging of the correctness of both deductions and calculations. By reference to my former paper it will be perceived that the ratio of penetration of some of the gases as there stated is erroneous, although not to an extent subversive of the great general truths there set forth. Cyanogen, ammonia and sulphureted hydrogen are less unequally penetrant than I had supposed, and the extraordinary alteration of rate occasioned by imbuing a dry membrane with water, was not then clearly enough expressed. The relation of oxygen and carbonic acid to each other, being that which is to the physiologist much the most interesting and important, has been studied in a greater number and variety of experiments, and so far as they are connected with the subject, it has been fully elucidated. For the rest, much remains to be done; and after I have examined in detail the relations of a similar kind between liquids, and the relation of both kinds of fluids to the blood, it is not improbable that new light will be shed on the dark subject of respiration.

Enough has now been done to show that the law of diffusion through stucco, established so well by Mr. Graham's very philosophical labours and reasoning, does not apply to substances of a closer texture, and that physiology must depend on the experiments on animal membranes themselves, for the elucidation of the many important difficulties in the way of a satisfactory explanation of the functions connected with aeriform fluids.